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Hatchability of post-peak egg production broiler breeder eggs as influenced by pre-incubation warming

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HATCHABILITY OF POST-PEAK EGG PRODUCTION BROILER BREEDER EGGS AS INFLUENCED BY PRE-INCUBATION WARMING

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ABSTRACT

This research was conducted to determine the effects of pre-incubation warming on the hatchability of post-peak egg production broiler breeder eggs. An experiment with six trials was conducted with 7,920 freshly laid eggs from Ross 308 and 708 broiler breeders from 61-67-wks of age. For each trial, 1,320 eggs were used to determine if pre-incubation warming treatments of 0, 2, 4, and 6, or 0, 3, 6, and 9, or 0, 9, 12 and 15 hrs (at 37.6°C) could improve the hatchability of eggs stored (at 15.5°C) for three days. After a storage period of three days, the eggs were incubated for 21d. Unhatched eggs were broken to determine fertility, and if fertile, stage of embryonic death. Time of hatch was observed for pre-incubation warming treatments 0, 9, 12, and 15 hrs. Of the chicks that hatched, two trials were conducted, each using 192 randomly selected males to determine if the pre-incubation warming treatments affected initial weight, final weight, average daily gain, or feed conversion ratio. Statistical significance was assessed at $P < 0.05$. Pre-incubation warming of 6 hrs or less did not significantly affect fertile hatchability, total hatchability, embryonic morality or pips. However, pre-incubation warming of 15 hrs negatively affected early-dead mortality (11.6%) when compared to eggs that did not receive any pre-incubation warming (8.7%). Pips were significantly reduced in eggs that were treated for 9, 12 and 15 hrs (1.4, 1.3, and 0.3%, respectively) when compared to eggs that did not receive pre-incubation warming (2.4%). Average hatch time was shortened by pre-incubation warming of 9, 12, and 15 hrs with differences of 5, 7, and 12 hrs, respectively, compared to the eggs that were not pre-incubated. Average final weight, average daily gain, and feed conversion ratio were not significantly different at the end of an 18d trial period. The results of this study provide evidence that

pre-incubation warming within a range of 2-15 hrs does not improve hatchability of post-peak broiler breeder eggs when stored for three days. The most significant finding is that eggs can be pre-warmed at incubation temperature for 15 hrs without negatively affecting hatchability.

INTRODUCTION

Poultry is the largest income producing animal commodity in Louisiana, exceeding the combined value of all other animal commodities, including beef cattle, dairy, swine, and sheep. The Louisiana poultry industry is primarily a broiler industry, consisting of three broiler complexes, a processing plant, and numerous growers for a South Arkansas complex. Because the Louisiana Legislature recognizes the importance of the production of poultry and eggs to the state's economy, September 2007 has been declared Louisiana Poultry and Egg Month (Kennard, 2007).

More than one billion pounds of broiler meat are produced in Louisiana each year with a gross value of over $700 million. This total, including value added poultry products, is in excess of one billion dollars annually. To maintain this high level of production, more than three million broiler breeder eggs are set each week. Despite the high profitability of the broiler industry, broiler breeders are the most reproductively inefficient types of commercially raised chicken, and are only second to turkeys. An increase in hatchability of broiler breeder eggs, even as small as only one percent, would increase cost effectiveness tremendously. This degree of improvement would be highly desirable on both a national and international scale.

In an ideal setting, every fertile broiler breeder egg would produce a healthy chick. Unfortunately, this is never the case in a commercial hatchery. There are many factors contributing to the failure of a fertile egg to hatch, also known as embryonic mortality, and these include: lethal genes, insufficient nutrients in the egg, and the fact that the egg may be exposed to conditions that do not meet the needs of the developing embryo. The same incubation and egg handling techniques that were developed more

than half a century ago are still used today, although today's broiler is considerably different from those of the 1950s.

The reproductive inefficiency of broiler breeders increases with age. In post-peak (greater than 30 weeks of age) broiler breeders, the hatchability of their eggs decreases by 15% (Leeson and Summers, 2000). Shell quality also declines with breeder age, resulting in lower hatchability (Roque and Soares, 1994). Although improvements have been obtained over the years in livability and in feed efficiency, similar improvements have not been gained in hatchability. This reduced hatchability of eggs from post-peak broiler breeders is a result of many contributing factors, including: larger egg size (Leeson and Summers, 2000), increased early and late embryo mortality (Hagger *et al.* 1986; Elibol and Brake, 2003), poorer shell quality (North and Bell, 1990), and other complications unique to large eggs from post-peak broiler breeders. It is evident that egg management and incubation procedures need to be altered, as current recommended egg management and incubation procedures are not adjusted for breeder age.

LITERATURE REVIEW

The process from the time of egg formation to hatching is very complex, and the hatching results may be influenced by many factors. The reproduction process can be divided into a pre-incubation period and an incubation period. Hatchability of fertile eggs is easily impacted by various management decisions during these periods. The pre-incubation period can be further divided, but will ultimately represent the time at which the egg is fertilized until it is set in the incubator. This includes collection at the farm, transportation to the hatchery, and storage at the hatchery prior to setting.

Current incubation requirements and practices have been summarized by Wilson (1991). These practices include setting eggs large end up, turning once per hour and providing a temperature of 37.5°C, and a relative humidity of 60% during the first 19d of incubation. During the last two days the temperature should be decreased to 37.0°C, and the humidity increased to 75%. At this time it is no longer necessary for eggs to be turned. Despite following all the precise incubation requirements for the successful hatch of fertile eggs, it is necessary to understand how some biological factors limit the hatchability of eggs from post-peak broiler breeders.

Egg Quality

In a study conducted by Kirk *et al.* (1980) which tested the performance of peak and post-peak broiler breeders, it was observed that fertility and hatchability decreased with age. Fertility of the post-peak broiler breeders (60 wks) in this study declined by 11%, and hatchability declined 9% in eggs weighing more than 70g. This effect was explained in part by a relationship between breeder age and egg weight, as younger breeders produced eggs with superior hatchability at an average weight of 60g. This

same effect was observed by Reis *et al.* (1997) who also examined weight loss as an effect of evaporation between large eggs from post-peak broiler breeders, and small eggs from young broiler breeders. They found eggs from older breeders tended to lose more weight in grams but less in percentage when compared to eggs from younger breeders. This can be explained by the associated increase in egg weight, as larger eggs have less shell area per unit of interior egg weight than smaller eggs (Kirk *et al.* 1980; North and Bell, 1990; Reis *et al.* 1997; Roque and Soares, 1994). Secondly, as egg size increases, yolk size increases more than the quantity of albumen (North and Bell, 1990; Zakaria *et al.* 2005).

As one might assume, larger eggs produce larger chicks (Lourens *et al.* 2006). Consequently, Romanoff (1936) used the ratio of the weight of the chick at hatching and the original weight of the egg to measure incubation efficiency. It was concluded that the highest ratios correlated with the temperature that resulted in the best hatchability. Chicks that hatch from older breeder flocks are usually larger, and of higher quality because they are naturally more resistant to dehydration upon hatching as compared to smaller chicks from young breeder flocks (Sinclair *et al.* 1990). However, these larger eggs require a longer hatching time. Large eggs, compared to other eggs produced in the same flock, will take about 12 hrs longer to hatch than smaller ones (Parkhurst and Mountney, 1988). This is true even across species. Chicken eggs require an incubation period of 21d, while larger eggs from larger birds such as turkeys and peafowl require 28d. In light of this material, incubation conditions should be adjusted to those more suited to older flocks (Kirk *et al.*1980).

Embryonic Mortality

In a review of the effects of incubator design on embryonic development, French (1997) suggests reducing machine temperature when incubating larger eggs since metabolic heat production is not constant throughout incubation. Rather, eggs are endothermic during the first half of incubation, and then become exothermic as embryonic development proceeds. Consequently, larger eggs have been observed to produce more heat (French, 1997). This reportedly led to a decline in hatchability as a result of increased embryonic mortality. There are three periods of embryonic mortality: early, middle and late. The early dead embryo mortality period represents eggs that die during the first seven days of incubation. The death is usually a result of failure of the embryo to resume development after having been stored and placed in the setter (North and Bell, 1990). The mid-dead embryo mortality period represents the eggs that die between day eight and 14 of incubation. The death is usually related to nutritional deficiencies in the broiler breeder diet or embryonic abnormalities. The late dead embryonic mortality peak represents the eggs that die during the last week of incubation. In this case, death is often due to abnormal positioning, complications in physiological changes, and lethal genes. Hatchability can also be impaired when the machine temperature fluctuates (Lourens *et al.* 2005), as confirmed by Yalcin and Siegel (2003) who noticed impaired lung development in embryos exposed to cold and heat during incubation.

Hatching eggs should be collected at the farm at least four times a day, but more frequent collection may be necessary during periods of extreme temperature, either high

or low (North and Bell, 1990). Once an egg is laid (oviposition), the hen begins to partially incubate, or pre-incubate the egg by keeping it warm. It is necessary to collect eggs frequently to prevent pre-incubation warming on the part of the hen, as this decreases uniformity of hatching time. Also, there is some research that suggests hatchability of fertile eggs can be related to the time of day at which eggs are laid (McNally and Byerly, 1936).

The stage of embryonic development at oviposition influences hatching results (Meijerhof, 1992). At the time of oviposition, the embryo has a chronological age of approximately 24-26 hrs, as fertilization occurs within 15-20 min of ovulation (Howarth, 1970; Bakst and Howarth, 1977; Parkhurst and Mountney, 1988). Perry (1987) observed the first cleavage division in the germinal disc at four hours after ovulation. Variation of embryo size occurs more significantly between hens, but also within a clutch (Taylor and Gunns, 1935). These differences in embryo size may be a result of the amount of time the egg is retained within the oviduct. More importantly, it has been found that the blastoderm area in fresh unincubated eggs increases with parental age (Mather and Laughlin, 1979). Therefore, embryonic development of embryos in eggs laid by post-peak broiler breeders is advanced, which may lead to an earlier hatch time as observed by Crittenden and Bohren (1962). Taylor and Gunns (1935) did not agree with this, reporting the size of the embryo in the unincubated egg was not found to be correlated with hatchability.

Stage of embryonic development has also been correlated with body weight. Coleman and Siegel (1966) reported that hens selected for low body weight at 8 wks of age produced eggs with advanced embryonic development at oviposition and an

increased hatchability when compared to eggs from hens that were selected for high body weight. They suggested that advanced embryonic development at oviposition is perhaps beneficial in helping the embryo to withstand storage.

Egg Storage

Ideally, hatching eggs should be set immediately after they are laid to reduce storage problems and optimize hatchability. This is rarely practical, and some storage is always necessary. The main reason for on-farm storage is to minimize transportation costs incurred by the hatcheries, which would be high with daily egg pick-up (Fasenko *et al.* 2001). Numerous studies have confirmed that when appropriate storage conditions are maintained, fertile eggs can be stored for several days without a major loss in hatchability. However, it is common practice to avoid storing eggs beyond seven days (Mayes and Takeballi, 1984). Currently, the poultry industry usually stores eggs for only three to four days as it is widely believed that hatchability declines significantly thereafter. Kirk *et al.* (1980) reported that the rate of decline in hatchability is greater in stored fertile eggs from older flocks. Reis *et al.* (1997) confirmed that in older hens, the viability of eggs not submitted to storage was higher by 3-6% than that of stored eggs. Mather and Laughlin (1979) found that an increased storage period lead to a higher prevalence of abnormalities, such as facial defects. Despite the known effects of egg storage on post-peak broiler breeder eggs, commercial hatcheries show no regard for flock age when handling eggs.

After careful collection of fresh eggs, they are stored in a cooler on the farm at a temperature of 18.3°C (North and Bell, 1990). Brake *et al.* (1997) suggests eggs from older hens be quickly placed in a cooler to maintain hatching quality. There is a period of

time during which the contents of the egg reach equilibrium with respect to ambient temperature after having been placed in the cooler. This period of cooling is largely dependent on the type of storage containers being used. In sealed egg cases, the eggs take four to five days to cool completely, the same cases with holes in the side only take two days, and in incubator egg trays the eggs take 18 hrs to cool completely (North and Bell (1990). The temperature at which cell division is stopped is known as physiological zero. Although dormancy of the embryo is maintained below the physiological zero, morphology of the embryo is not static (Meijerhof, 1992). According to North and Bell (1990) physiological zero is 23.9°C, although it was reported by Edwards (1902) to be between 20 and 21°C. Funk and Biellier (1944) suggested that the temperature is even as high as 28°C.

Storage Temperature

Many researchers have investigated the effect of storage temperature on the hatchability of fertile eggs, with an outcome suggesting there is an acceptable range dependent upon the duration of storage. Wilson (1991) has reviewed the literature reporting that optimum storage temperature should decrease as length of storage is increased. In general, suggested temperatures are: 20-25°C when storing eggs for less than four days; 16-17°C for four to seven days; and 10-12°C for storage of more than seven days. Findings by Kirk *et al.* (1980) confirm that during the first week, the shorter the storage period, the higher the optimum storage temperature for the best hatching results. A study by Ruiz and Lunam (2002) revealed an improvement in hatchability of fertile eggs from older hens by reducing early embryonic death. This was accomplished by reducing storage temperature from 16.5°C to 10°C during prolonged storage (Ruiz and Lunam, 2002). However, prolonged storage may have adverse effects on fertile eggs,

such as delaying the initiation of development of the embryos following storage (Mather and Laughlin, 1979). Christensen *et al.* (2003) found that this delay in embryonic development may be compensated by increasing machine temperature during the first periods of incubation.

Water is lost through evaporation during storage, with the amount of loss being influenced by relative humidity (RH), temperature, and shell porosity. Mayes and Takeballi (1984) concluded that attempts should be made to prevent water loss because it negatively affects hatchability. The recommended relative humidity when cooling and storing eggs is 75% (North and Bell, 1990). A relative humidity of 75% is practical for the industry as a higher level may result in moisture build-up and serve as a vector for bacterial contamination (Meijerhof, 1992).

Pre-incubation Warming

Warming eggs before incubation (pre-incubation warming) has been shown to affect the hatchability of eggs from both chickens and turkeys. In fact, heating eggs just prior to setting is reported to improve hatchability (Meijerhof, 1992). Pre-incubation warming can be administered prior to storage (Becker and Bearse, 1958; Fasenko *et al.* 2001a, 2001b; Lancaster and Jones, 1986; McConachie *et al.* 1960; North and Bell, 1990; and Olsen, 1949), during storage (Kan *et al.* 1962; Kosin, 1956; and Milby and Sherwood, 1960), or for a few hours immediately before setting (Proudfoot, 1970). There is, however, conflicting reports of how much warming is necessary for improving hatchability, which may be the result of wide ranges of storage periods and storage conditions used for these published papers.

Pre-incubation Warming Prior to Storage

Fasenko *et al.* (2001a) reported significantly improved hatchability of turkey breeder eggs that were pre-incubated for 12 hrs and then stored for 14d. Subsequently, Fasenko *et al.* (2001b) observed similar results with broiler breeder eggs. They concluded that although their experiment yielded best results with a pre-incubation treatment of six hours and 14d storage period, the actual optimum pre-storage incubation treatment may be somewhere between zero and 12 hrs. Lancaster and Jones (1986) had similar results when pre-incubating eggs before prolonged storage. Their best results occurred in eggs treated for less than five hours when stored for a period greater than eight days, coming from a breeder flock that was experiencing less than "high hatchability".

Becker and Bearse (1958) investigated the effect of pre-incubating eggs at 37.8°C for a period of one or five hours, immediately before prolonged storage. This was done after the eggs had either been stored overnight in a cooler at 10°C, 85% RH, or left out in the incubator room at 21.1-22.8°C, 45% RH. Eggs that were treated with one hour of pre-incubation warming and those left out overnight experienced an average increase in hatchability of nearly 5%. It was reported that eggs stored for longer periods benefited most from the treatment, which is in agreement with findings by Lancaster and Jones (1986). This was not confirmed by McConachie *et al.* (1960) who reported no beneficial effects after storage of more than five days. Becker and Bearse (1958) also commented that "Eggs from matings that produced lower hatchability benefited the most from the different warming treatments."

In a study conducted by Olsen (1949), it was reported that eggs exposed to pre-incubation warming, followed by commercial shipment of approximately 48, 72, and 96

hrs showed an increase in hatchability. The eggs were pre-incubated for 18 hrs and displayed a greater hatchability when compared to control groups that did not experience pre-incubation warming. Secondly, the experimental eggs were candled immediately after the 18 hr treatment period and infertile eggs were removed prior to shipment (with an accuracy of 90%). Significance of these findings was placed on the ability to send and receive noticeably fertile eggs, thereby minimizing transportation cost incurred by invariably shipping eggs with an unknown fertility. More specifically, this means that by candling eggs at 18 hrs of incubation, and shipping only those that appear fertile, approximately 11 of every 12 infertile eggs can be discarded at the source of supply.

According to North and Bell (1990), "hatching eggs are pre-incubated to increase the percentage of hatchability." They suggest heating the eggs to 38.2°C for six to eight hours prior to storage. They noticed that pre-incubating eggs close to normal incubation temperature results in a shortened incubation period by a time equal to the length of the pre-incubation.

Pre-incubation Warming During Storage

Kosin (1956) took a different approach to pre-incubation warming by conducting it throughout the storage term. The eggs were exposed for one hour to a temperature of 37.6°C, each day for a period of 14d. Consequently, hatchability improved as much as 4% in eggs stored for one to seven days, and 6% in eggs stored for eight to 14d. These findings were confirmed by Kan *et al.* (1962) when increased hatchability was observed in eggs pre-incubated at 37.5°C and stored up to three weeks. However, eggs that were stored for 22-28d responded negatively to the pre-incubation warming treatment, as was indicated by a drop in hatchability of nearly 50%. They concluded that warming the eggs

the day after they were laid proved to be the most effective time for pre-incubation warming.

Pre-incubation Warming Immediately Before Setting

Proudfoot (1970) stored eggs for seven and 14d in coolers with temperatures ranging from 11-23°C as a way to emulate transportation conditions when shipped by air. The pre-incubation warming treatments were carried out 18 hrs prior to setting. Although the results show an improvement in hatchability of eggs receiving the pre-warming treatments, the standard control group of eggs ultimately had the best reported hatchability. The explanation for this may be that a higher hatchability can be achieved when maintaining a constant storage temperature, as compared to the experimental design of this particular research where in eggs experienced three different holding temperatures before ever reaching the incubator. These results strengthen the conclusions reached by Kosin (1956): "Beneficial effects of pre-incubation warming prior to storage or during storage may be explained by the assumption that an advanced stage of development of the blastoderm is beneficial in helping the embryo to withstand storage." And again, warming the eggs the day after they are laid proved to be the most effective time for pre-incubation (Kan et. al., 1962). It can be assumed that waiting until after prolonged storage to treat fertile eggs with pre-incubation warming regimens is perhaps too late.

In summary, hatching eggs produced by post-peak broiler breeders have been shown to be larger in size and of poorer shell quality. They also exhibit a reduced fertility, increased embryonic mortality, and decreased uniformity of hatch time. The research reports also show a significant drop in hatchability after storage within optimum conditions.

Numerous articles have been published concerning the improvement of hatchability of eggs by pre-incubation warming when stored for long periods of time. These research reports have concluded that broiler breeder eggs can withstand extended storage more effectively when pre-incubation warming regimens are implemented. However, there is little information on the benefits of pre-incubation warming when eggs are stored for normal periods. In addition, there is no information specific to post-peak broiler breeders. These procedures may improve hatchability of eggs from post-peak broiler breeders produced and stored under normal commercial conditions. Post-peak broiler breeders were chosen for this study because they have more room for improvement than breeders at all other stages of production, and therefore are more likely to demonstrate a response to treatment. Post-peak broiler breeders are also the least profitable, and incidentally even a small increase in hatchability could extend the profitable life of the flock. Thus, the following trials were conducted.

MATERIALS AND METHODS

Trials 1 and 2

A total of 1320 eggs laid within a two hour time frame were obtained from two commercial breeder farms and transported for two hours to the LSU Poultry Farm. The eggs specifically came from two flocks of 61-wk old Ross 308 broiler breeders. Immediately upon their arrival at LSU, the eggs were randomized before being assigned to a treatment group. The eggs were set in trays and numbered from 1 to 330 for each treatment of pre-incubation warming of either 0, 2, 4, or 6 hrs. Eggs in the 0 hrs treatment group were immediately placed in an egg cooler at 15.5°C at a relative humidity of 60%.

Eggs receiving the pre-incubation warming treatments were placed in a Natureform setter (#2000, Jacksonville, FL, 32202) operating at 37.6°C at the same time, and the appropriate groups of eggs were removed after 2, 4, and 6 hrs. After removal from the setter, the eggs were transferred from incubator trays to cardboard egg flats, which were then placed in the same cooler as the control group for three days. The transferring of the eggs from incubator trays to egg flats was done to match the storage conditions of the control group of eggs which received 0 hrs pre-incubation warming. After completion of the three day storage period, the eggs were set in a randomized block design for 18d. Level and position within the incubator were randomly assigned. A total of 11 levels in the Natureform incubator were used for the trial, with six positions within each level (Figure A1). Each position held 30 eggs, and only the four corners of a level were filled with experimental eggs. The two middle positions were filled with non-experimental eggs so that air flow was unaffected. On day seven of incubation, the eggs

were candled and the infertile and early fertile dead embryos were removed and broken to confirm infertility or embryonic mortality. On 18d of incubation, the treatment groups were transferred to a Natureform hatcher (#NOM-45, Jacksonville, FL, 32202) operating at 37.0°C and relative humidity of 75%. Level within the incubator was maintained in the hatcher at time of transfer. After 21d of incubation, the chicks were removed and counted. All the unhatched eggs were removed and pips were counted. The remaining unhatched eggs were broken for identification of embryonic mortality. All embryos were classified as early dead, mid-dead, or late dead as defined by death during either the first, second, or third week of incubation, respectively.

The variables measured were percent true fertility, percent fertile hatchability, percent early dead, percent mid-dead, percent late dead, percent pips, and percent total hatchability. In Trial 2, all of the procedures and treatments were the same as Trial 1. The same number of eggs was obtained from two 61-wk old flocks of Ross 308 broiler breeders and transported for two hours to the LSU Poultry Farm.

Trials 3 and 4

Again, a total of 1320 eggs laid within a two hour time frame were obtained from a commercial breeder farm and transported for two hours to the LSU Poultry Farm. The eggs specifically came from two flocks of 64-wk old Ross 308 broiler breeders. All of the procedures followed in Trials 1 and 2 were the same in Trial 3, except the pre-incubation warming treatments were 0, 3, 6, and 9 hrs. Trial 4 was conducted exactly as Trial 3 except that the eggs came from two commercial flocks of 67-wk old Ross 308 broiler breeders.

Trials 5 and 6

A total of 1320 eggs laid within a two hour time frame were obtained from a commercial breeder farm and transported for four hours to the LSU Poultry Farm. The eggs specifically came from two flocks of 61-wk old Ross 708 broiler breeders. The procedures were the same as in the previous trials, except the pre-incubation warming treatments were 0, 9, 12, and 15 hrs.

At the time of transfer (18d), eggs from each level were transferred into a hatching basket. Pedigree baskets were used to separate the treatments. Level in the setter was the same in the hatcher. The eggs were monitored every six hours from the time of transfer until 12 hrs after the 21d incubation period had passed, and hatched chicks were counted and removed. Chicks of the same treatment were consolidated in regular hatching baskets and held in the hatcher until the trial was completed.

In order to test the effects of pre-incubation warming on chick growth, a total of 192 Ross x Ross male chicks were randomly selected and allotted by the original four treatments into six replications in a completely randomized design. Each treatment-replication group consisted of eight chicks. The chicks were fed a standard broiler starter diet as prescribed by Aviagen/Ross (Table 1). The chicks were wing banded and grown for 18d. All chicks were weighed to the nearest gram at the beginning of the trial period and again at the end. They were housed in a Petersime starter battery (#2SD-24, Gettysburg, OH, 45328) with raised wire floors. Feed and water were provided on an ad libitum basis throughout the experiment. Chicks, feed and water were checked twice daily and mortality, if any, was recorded. In Trial 6, all of the procedures and treatments

Table 1. Percentage composition of the broiler starter diet, as fed basis.

Ingredient	(%)	Calculated Analysis	
Corn	52.916	ME, kcal/kg	3,025
Soybean meal	38.808	Crude protein (%)	23.30
Poultry fat	3.103	Calcium (%)	1.11
Monocal	1.734	NonPh Phos (%)	0.50
Limestone	1.672	Lysine (%)	1.43
Salt	0.5	TSAA (%)	1.07
DL-Methionine	0.337		
Biolys	0.25		
Mineral premix[1]	0.25		
Vitamin premix[2]	0.25		
L-Threonine	0.13		
Choline chloride	0.05		

[1] Provides the following per kilogram of diet: Fe, 50 mg; Mn, 100 mg; Cu, 7 mg; Se, 0.15 mg; Zn 75 mg; I, 1 mg, as ferrous sulfate monohydrate, manganese sulfate, copper sulfate, sodium selenite, zinc sulfate, ethylenediamine dihydriodide, respectively with calcium carbonate as the carrier.

[2] Provides the following per kilogram of diet: vitamin A, 8,000 IU; vitamin D_3, 3,000 IU; vitamin E, 25 IU; vitamin K, 1.5 IU; riboflavin, 10 mg; pantothenic acid, 15 mg; niacin, 50 mg; vitamin B_{12}, 0.02 µg; biotin, 0.1 µg; folic acid, 1 mg; pyridoxine, 4 mg; and thiamin, 3 mg.

were the same as in Trial 5. The eggs were obtained from two flocks of 61-wk old Ross 708 broiler breeders, and transported for four hours to the LSU Poultry Farm.

Statistical Analysis

The pre-warming incubation trials were initially designed to consider the randomly assigned independent variables, level in the setter (block), and position within level. Position within level and its interactions were not significant in any trial so these variables were removed from the model. In addition, none of the level in setter interactions were significant in any of the trials. These variables were also removed from the model. Before similar trials were combined, they were tested for significant trial by treatment interactions. None of the interactions of the main effect trial were significant. The trials were combined and the interaction terms removed from the model. Thus, the reduced model contained the independent variables, trial, level and treatment in a randomized block design. When significant treatment effects were found, prediction equations were used to graph quadratic and cubic polynomial regression models (SAS, 1996). Hatchability data were analyzed by analysis of variance procedures appropriate for a randomized block design, using PROC ANOVA procedures of the Statistical Analysis System (SAS, 1996). Arcsine of the square root of the variable was used to convert all percentages prior to analysis. The flat of 30 eggs was the experimental unit for all hatchability trials. The hatch time data were analyzed using the GLM procedure, with a cubic polynomial regression model (SAS, 1996). The broiler grow-out trials were arranged in a completely random design, with a pen of eight broilers as the experimental unit. Statistical significance was assessed at ($P < 0.05$). The appropriate amount of replication was ascertained using mathematical procedures in Cochran and Cox (1950).

RESULTS AND DISCUSSION

True fertility was not a response variable in this particular experimental research, as fertilization of the eggs occurred in the hens at the breeder farms. However, true fertility represents an important ratio that indicates the productivity of the breeder flock, as it is necessary in calculating embryonic mortality and fertile hatchability. In Trials 1 and 2, true fertility averaged approximately 92-94% which according to North and Bell (1990) is normal for broiler breeders of this age (Table 2). Since there were no significant trial by treatment interactions, Trials 1 and 2 were combined. Of all the response variables, there were no significant trial effects except with regard to late-dead ($P \leq 0.0051$). This difference may be attributed to variation between flocks. Fertile hatchability and total hatchability were not significantly affected by any of the pre-incubation warming treatments (Table 3). Total hatchability, with an approximate mean percentage of 81.8% corresponds with observations made by North and Bell (1990) and meets the performance objectives for Ross 308's set forth by Aviagen (2007). Embryo mortality (early dead, mid-dead, and late dead), and total unhatched eggs as well as pips were also not significantly affected by treatment (Table 4). The periods of early dead, mid-dead, and late dead embryonic mortality, and percent pips (7.6%, 1.5%, 2.4%, and 0.8% respectively), are consistent with observations made by McDaniel *et al.* (1981). The lack of a significant treatment effect on fertile hatchability or any hatch variable measured is possibly due to the short three day storage period. In previous works (Fasenko *et al.*, 2001b, and Lancaster and Jones, 1986), the eggs were subjected to storage periods of two weeks and eight days, respectively. The storage period in this study was not as long as in the previous works and evidently not long enough to

Table 2. The main effect of trial on true fertility, fertile hatchability, total hatchability, early dead, mid-dead, late dead, pips, and total unhatched eggs from two flocks of 61-wk old Ross 308 broiler breeders pre-incubation warmed for 0, 2, 4, and 6 hrs (Trials 1 and 2 combined)[1].

Response Variable	Trial 1	Trial 2	P > F
	(%)		
True Fertility	94.0 ± 0.6	92.3 ± 0.7	0.0850
Fertile Hatchability	88.1 ± 0.9	87.4 ± 0.8	0.5387
Total Hatchability	82.9 ± 1.1	80.8 ± 1.0	0.1242
Early-dead	8.0 ± 0.7	7.2 ± 0.7	0.5771
Mid-dead	1.4 ± 0.3	1.6 ± 0.4	0.8463
Late-dead	1.7 ± 0.4	3.1 ± 0.4	0.0051
Pips	1.0 ± 0.3	0.6 ± 0.2	0.5421
Total Unhatched	12.1 ± 0.9	12.5 ± 0.7	0.3798

[1] Values are means ± SEM

Table 3. The effect of pre-incubation warming of 0, 2, 4, and 6 hrs on fertility, fertile hatchability, and total hatchability of eggs from two flocks of 61-wk old Ross 308 broiler breeders (Trials 1 and 2 combined)[1].

Pre Warm (Hrs)	True Fertility	Fertile Hatchability	Total Hatchability
	(%)		
0	95.0 ± 0.8	88.4 ± 1.5	83.6 ± 1.7
2	92.4 ± 0.8	87.8 ± 1.0	81.2 ± 1.2
4	91.8 ± 1.1	87.5 ± 1.3	80.5 ± 1.7
6	93.9 ± 0.9	87.3 ± 1.0	81.9 ± 1.2
P > F	0.1772	0.7976	0.4279

[1] Values are means ± SEM

Table 4. The effect of pre-incubation warming of 0, 2, 4, and 6 hrs on early dead, mid-dead, late dead, pips, and total unhatched eggs from two flocks of 61-wk old Ross 308 broiler breeders (Trials 1 and 2 combined)[1].

Pre Warm (Hrs)	Early dead	Mid-dead	Late dead	Pips	Total Unhatched
	(%)				
0	7.5 ± 1.1	1.1 ± 0.4	2.4 ± 0.6	0.5 ± 0.3	11.5 ± 1.4
2	7.2 ± 0.8	1.6 ± 0.5	2.8 ± 0.5	0.5 ± 0.3	12.1 ± 1.0
4	8.1 ± 1.0	1.2 ± 0.5	2.0 ± 0.6	1.3 ± 0.4	12.6 ± 1.2
6	7.6 ± 0.9	2.0 ± 0.5	2.4 ± 0.6	0.8 ± 0.3	12.8 ± 0.9
P > F	0.9782	0.4384	0.4609	0.3563	0.7842

[1] Values are means ± SEM.

demonstrate a significant response. The present research shows no significant difference in the hatchability of eggs that were immediately placed in a cooler, compared to eggs exposed to conditions of prolonged warming. These data do not agree with results reported by Brake *et al.* (1997) who suggested eggs from older hens should be quickly placed in a cooler to maintain hatching quality.

In Trials 3 and 4, true fertility averaged approximately 89% which according to North and Bell (1990) is normal for breeders of this age (Table 5). Since there were no significant trial by treatment interactions for Trials 3 and 4, they were combined. The breeders that produced these eggs were three to six weeks older than those used in the other trials, which is believed to be the cause for the significant ($P \leq 0.0002$, and $P \leq 0.0017$) differences in fertile hatchability and total hatchability, respectively. This effect is also observed as significant ($P < 0.0001$, and $P \leq 0.0469$) differences in early dead and late dead mortality, respectively. There was no significant difference observed for mid-dead mortality. There was however, a significant ($P \leq 0.0012$) difference in pips by trial. The trend of increasing embryonic mortality with flock age is in agreement with observations made by Hagger *et al.* (1986), and Elibol and Brake (2003). The high mean percentage of early dead embryos is responsible for increasing total unhatched eggs, and is significantly ($P < 0.0001$) different by trial. Fertile hatchability and total hatchability were not significantly affected by any of the pre-incubation warming treatments (Table 6). The periods of early dead, mid-dead, and late dead embryonic mortality, total unhatched eggs as well as pips were not significantly affected by treatment (Table 7). The mean percentage of fertile hatchability of approximately 66% for the pre-incubation warming treatments of 0, 3, 6, and 9 hrs was considerably lower compared to the other

Table 5. The main effect of trial on true fertility, fertile hatchability, total hatchability, early dead, mid-dead, late dead, pips, and total unhatched eggs from two flocks of 64 and 67-wk old Ross 308 broiler breeders pre-incubation warmed for 0, 3, 6, and 9 hrs (Trials 3 and 4 combined)[1].

Response Variable	Trial 3	Trial 4	P > F
	(%)		
True Fertility	89.4 ± 1.1	89.0 ± 1.0	0.6375
Fertile Hatchability	62.6 ± 1.3	69.8 ± 1.0	0.0002
Total Hatchability	55.9 ± 0.4	62.2 ± 0.3	0.0017
Early-dead	27.9 ± 0.7	16.4 ± 0.8	<0.0001
Mid-dead	1.6 ± 0.3	1.8 ± 0.6	0.5827
Late-dead	6.9 ± 1.4	8.7 ± 1.1	0.0469
Pips	1.0 ± 1.4	3.3 ± 1.2	0.0012
Total Unhatched	37.4 ± 1.4	30.2 ± 1.3	<0.0001

[1] Values are means ± SEM

Table 6. The effect of pre-incubation warming of 0, 3, 6, and 9 hrs on fertility, fertile hatchability, and total hatchability of eggs from two flocks of 64 and 67-wk old Ross 308 broiler breeders (Trials 3 and 4 combined)[1].

Pre Warm (Hrs)	True Fertility	Fertile Hatchability	Total Hatchability
	(%)		
0	89.7 ± 1.5	67.2 ± 1.4	60.1 ± 1.3
3	87.2 ± 1.6	65.3 ± 1.9	57.0 ± 2.0
6	89.9 ± 1.4	65.2 ± 2.3	58.7 ± 2.4
9	90.0 ± 1.3	67.1 ± 2.4	60.3 ± 2.3
P > F	0.4263	0.8011	0.6034

[1] Values are means ± SEM.

Table 7. The effect of pre-incubation warming of 0, 3, 6, and 9 hrs on early dead, mid-dead, late dead, pips and total unhatched eggs from two flocks of 64 and 67-wk old Ross 308 broiler breeders (Trials 3 and 4 combined)[1].

Pre Warm (Hrs)	Early dead	Mid-dead	Late dead	Pips	Total Unhatched
	(%)				
0	22.0 ± 1.9	1.5 ± 0.5	6.7 ± 1.0	2.6 ± 0.9	32.8 ± 1.5
3	22.3 ± 2.1	1.8 ± 0.6	8.6 ± 1.0	2.1 ± 0.5	34.8 ± 2.1
6	22.3 ± 2.0	2.3 ± 0.5	7.8 ± 1.0	2.4 ± 0.8	34.8 ± 2.2
9	22.0 ± 2.3	1.4 ± 0.5	8.1 ± 1.2	1.4 ± 0.5	32.9 ± 2.5
P > F	0.9907	0.4823	0.7431	0.7125	0.8280

[1] Values are means ± SEM.

trials. Subsequently, the mean percentage of total hatchability was approximately less than 60%. Again, these observations can be explained by an increased early dead embryonic mortality, and an increase in pips as an effect of breeder age.

True fertility differed significantly ($P \leq 0.0048$) in Trials 5 and 6, which may be attributed to variation between flocks (Table 8). True fertility averaged approximately 93-95% which according to North and Bell, (1990) is normal for breeders of this age. Again, there were no significant trial by treatment interactions for Trials 5 and 6, and they were combined. A significant ($P \leq 0.0109$) difference in fertile hatchability was observed as a result of significant differences in mid-dead, late dead, and total unhatched eggs ($P \leq 0.0238$, $P \leq 0.0002$, and $P \leq 0.0103$, respectively). Once more, these differences are likely a result of variation between breeder flocks. Fertile hatchability and total hatchability were not significantly affected by any of the pre-incubation warming treatments (Table 9). The mean percentages of fertile hatchability and total hatchability (87.6% and 82.4%, respectively) closely resemble the results in Trials 1 and 2. However, early dead mortality was significantly ($P \leq 0.0131$) affected by treatment (Table 10). Figure 1 gives the graph of the prediction equation for the relationship between pre-incubation warming and early dead mortality. As the period of pre-incubation warming increased, the percent pips decreased significantly ($P \leq 0.0224$). Figure 2 gives the graph of the prediction equation for the relationship between pre-incubation warming and pips. Despite the beneficial response of a decrease in pips, the heightened early dead mortality masked any positive response in fertile hatchability, as seen in the total unhatched eggs which was nearly equal for all treatments. There are several reports of improved hatchability resulting from pre-incubated eggs, but again, all

Table 8. The main effect of trial on true fertility, fertile hatchability, total hatchability, early dead, mid-dead, late dead, pips, and total unhatched eggs from two flocks of 61-wk old Ross 708 broiler breeders pre-incubation warmed for 0, 9, 12, and 15 hrs (Trials 5 and 6 combined)[1].

Response Variable	Trial 5	Trial 6	P > F
	(%)		
True Fertility	93.0 ± 0.7	95.4 ± 0.5	0.0048
Fertile Hatchability	88.9 ± 0.9	86.2 ± 0.8	0.0109
Total Hatchability	82.7 ± 1.0	82.2 ± 0.8	0.6148
Early-dead	9.0 ± 0.8	8.8 ± 0.7	0.8739
Mid-dead	0.4 ± 0.2	1.3 ± 0.4	0.0238
Late-dead	0.4 ± 0.2	2.2 ± 0.5	0.0002
Pips	1.3 ± 0.3	1.4 ± 0.3	0.7715
Total Unhatched	11.1 ± 0.8	13.7 ± 0.8	0.0103

[1] Values are means ± SEM

Table 9. The effects of pre-incubation warming of 0, 9, 12, and 15 hrs on fertility, fertile hatchability, and total hatchability of eggs from two flocks of 61-wk old Ross 708 broiler breeders (Trials 5 and 6 combined)[1].

Pre Warm (Hrs)	True Fertility	Fertile Hatchability	Total Hatchability
	(%)		
0	93.2 ± 1.2	87.3 ± 1.1	81.4 ± 1.6
9	94.6 ± 0.9	88.8 ± 1.6	83.8 ± 1.3
12	94.7 ± 0.7	87.4 ± 1.0	82.7 ± 1.0
15	94.2 ± 0.8	86.8 ± 1.0	81.8 ± 1.2
P > F	0.7314	0.3111	0.5562

[1] Values are means ± SEM.

Table 10. The effect of pre-incubation warming of 0, 9, 12, and 15 hrs on early dead, mid-dead, late dead, pips, and total unhatched eggs from two flocks of 61-wk old Ross 708 broiler breeders (Trials 5 and 6 combined)[1].

Pre Warm (Hrs)	Early-dead	Mid-dead	Late-dead	Pips	Total Unhatched
	(%)				
0	8.7 ± 1.0	0.3 ± 0.2	1.3 ± 0.5	2.4 ± 0.6	12.7 ± 1.1
9	7.3 ± 1.3	1.1 ± 0.6	1.4 ± 0.5	1.4 ± 0.5	11.2 ± 1.5
12	8.0 ± 0.9	1.4 ± 0.4	1.9 ± 0.7	1.3 ± 0.4	12.6 ± 0.9
15	11.6 ± 0.8	0.6 ± 0.3	0.6 ± 0.4	0.3 ± 0.2	13.1 ± 1.0
P > F	0.0131	0.1650	0.2536	0.0224	0.0985

[1] Values are means ± SEM.

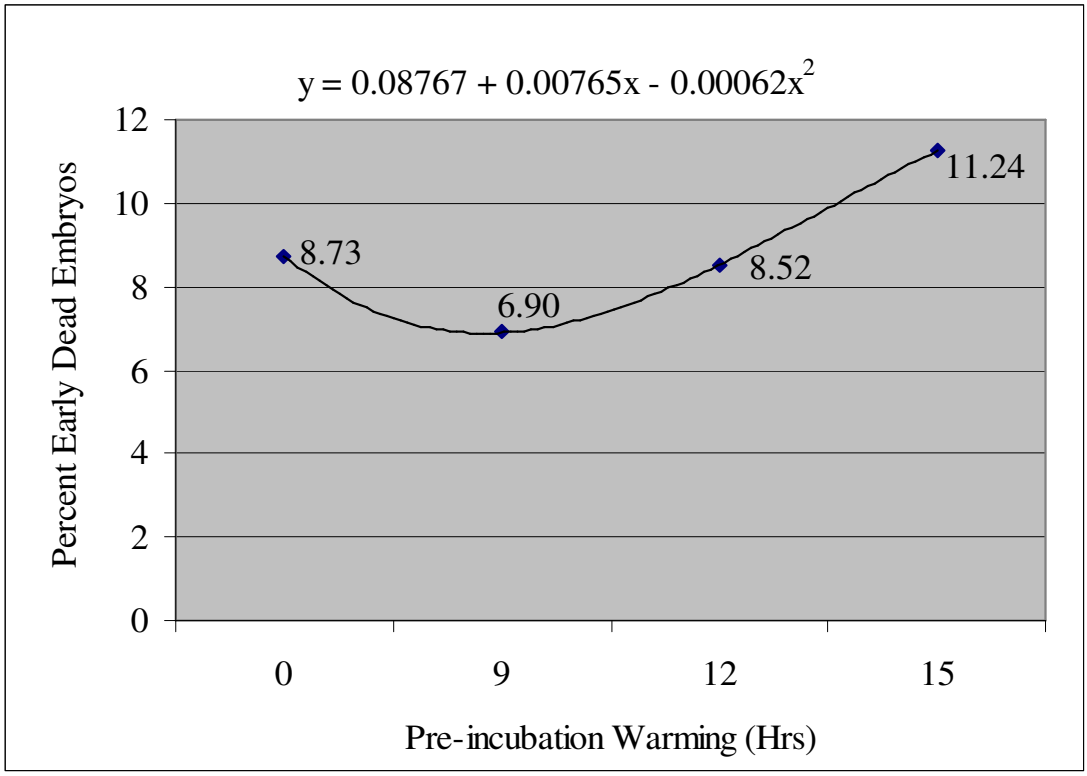

Figure 1. The effect of pre-incubation warming of 0, 9, 12, and 15 hrs on early dead mortality in eggs from two flocks of 61-wk old Ross 708 broiler breeders (Trials 5 and 6 combined).

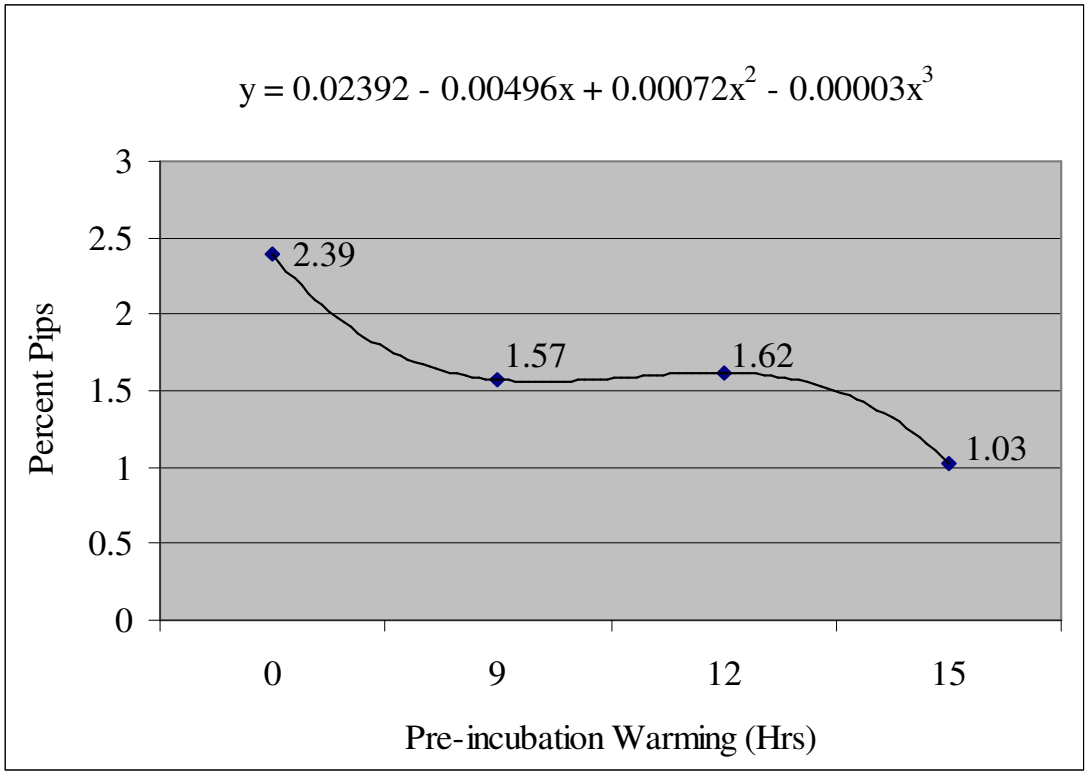

Figure 2. The effect of pre-incubation warming of 0, 9, 12, and 15 hrs on pips in eggs from two flocks of 61-wk old Ross 708 broiler breeders (Trials 5 and 6 combined).

such treatments were followed with periods of extreme storage length. Today's modern broiler industry simply does not have the capacity to hold eggs for periods of time simulated in these other experiments (Mayes and Takeballi, 1984). These data suggest that any positive effect of pre-incubation warming is likely only demonstrated when eggs are forced to remain in storage for periods that would not occur naturally.

Average incubation time was reduced in eggs receiving pre-incubation warming treatments of 9, 12, and 15 hrs by 5, 7, and 12 hrs, respectively (Figure 3). These results agree with findings by North and Bell (1990), who observed a shortened incubation period by a time nearly equal to that of the duration of pre-incubation. The graphs of peak hatch-time for Trials 5 and 6 can be seen in Figures 4 and 5, respectively.

When chicks were selected for the battery trial, it was found that average chick starting weights were significantly ($P \leq 0.0032$, and $P \leq 0.0046$) different when eggs were exposed to increasing hours of pre-incubation warming (Tables 11 and 12, respectively). Chick weights were not measured until all treatments had completed hatching, and thus the older chicks were more vulnerable to dehydration as a result of the delay. The dehydration effect as seen in body weight appeared to plateau in Trial 5 as pre-incubation warming increased (Figure 6). However, eggs that were pre-incubation warmed for 15 hrs in Trial 6 produced chicks that seemed to experience a heightened effect of dehydration (Figure 7). Chick weights were higher than those listed in Aviagen's performance objectives for Ross 708 males (2007), but this difference can be explained by the relationship between breeder age, egg size, and chick size. It is well known that egg size increases with breeder age, and that chick size is directly related to egg size (Leeson and Summers, 2000; Kirk *et al.*, 1980; Lourens *et al.*, 2006; and

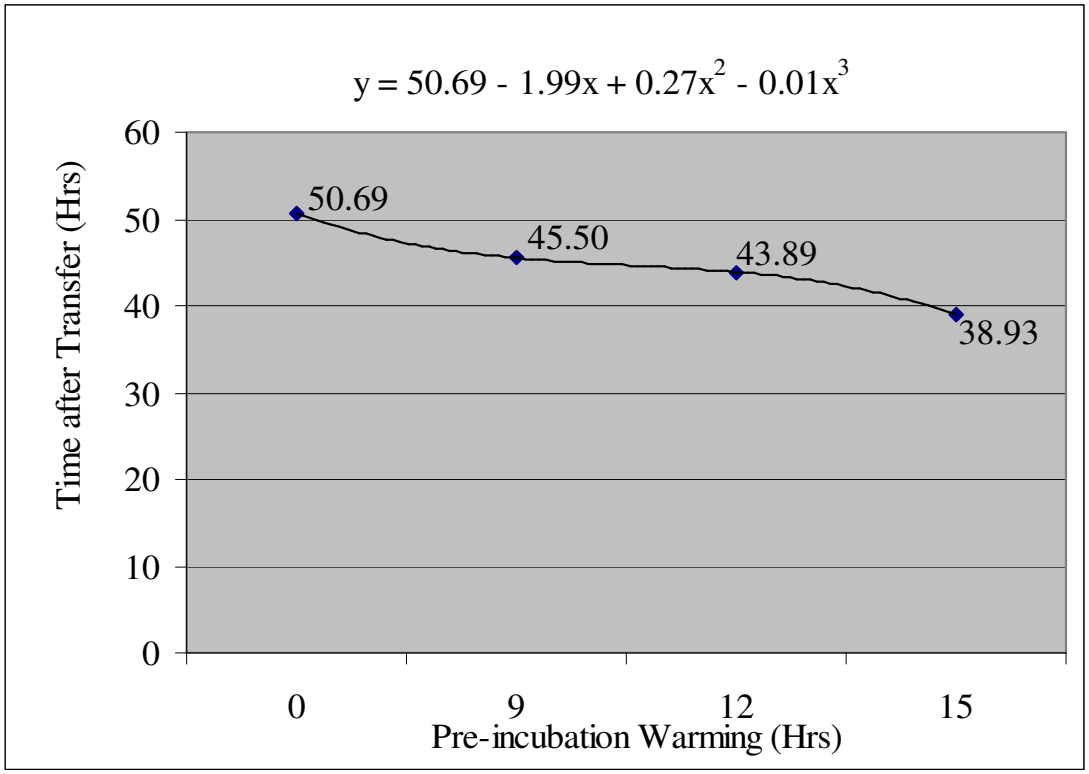

Figure 3. The effect of pre-incubation warming of 0, 9, 12, and 15 hrs on average hatch time after transfer of chicks from two flocks of 61-wk old Ross 708 broiler breeders (Trials 5 and 6 combined).

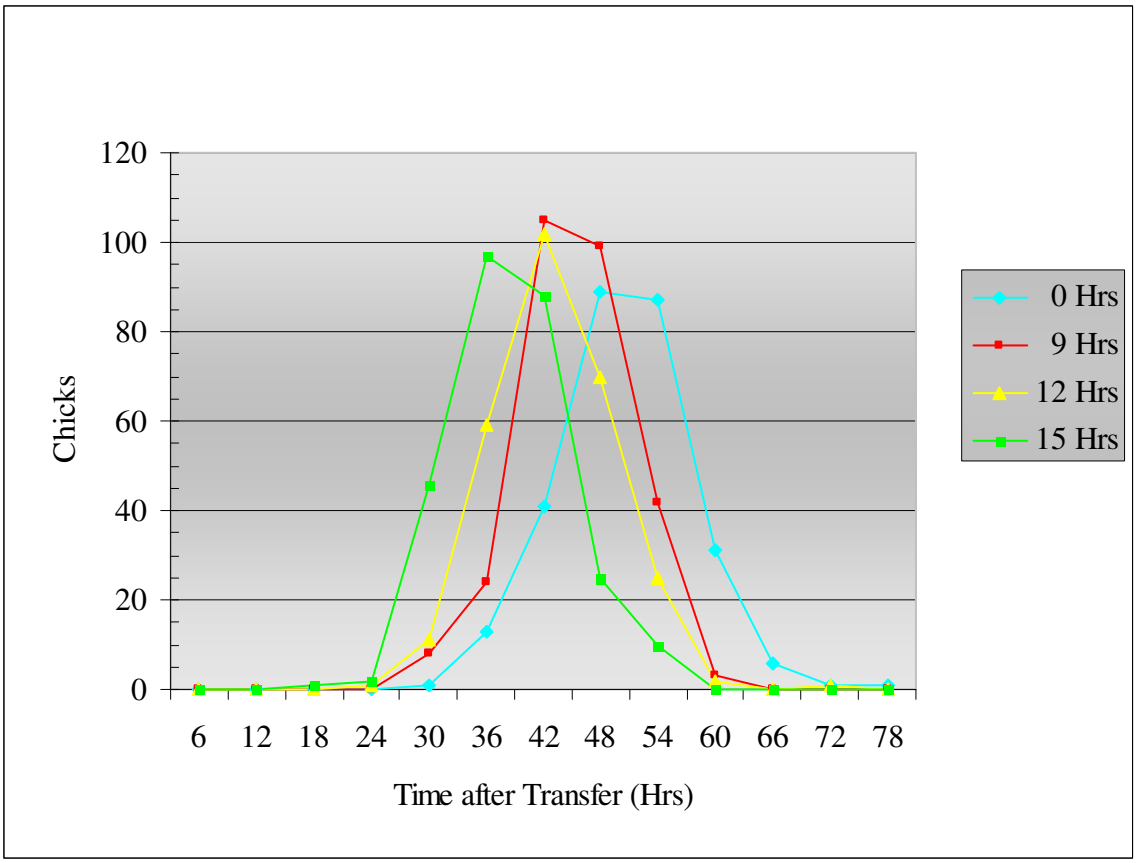

Figure 4. Effect of pre-incubation warming of 0, 9, 12, and 15 hrs on the acceleration of hatch time of eggs from two flocks of 61-wk old Ross 708 broiler breeders (Trial 5).

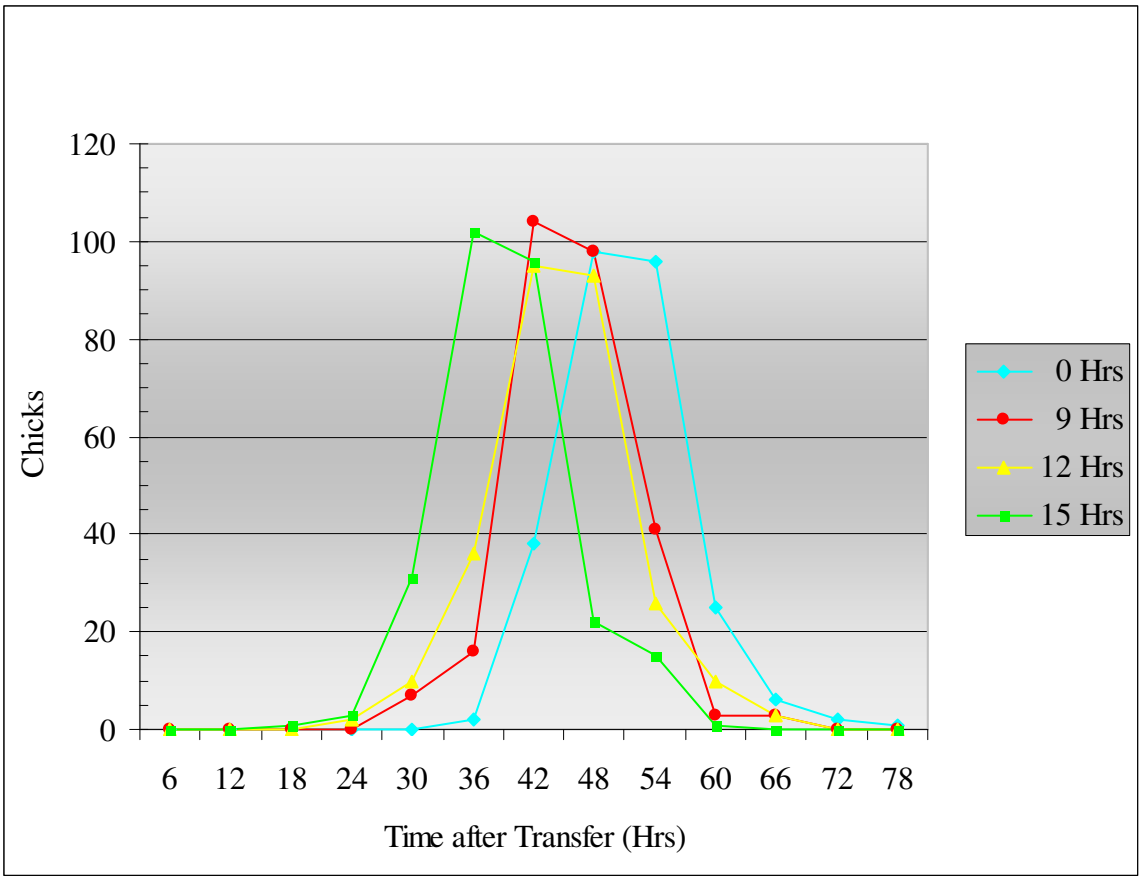

Figure 5. Effect of pre-incubation warming of 0, 9, 12, and 15 hrs on the acceleration of hatch time of eggs from two flocks of 61-wk old Ross 708 broiler breeders (Trial 6).

Table 11. The effects of pre-incubation warming of 0, 9, 12, and 15 hrs on initial weight (INWT), final weight (FWT), average daily gain (ADG), and feed conversion ratio (FCR) on Ross 708 male broiler chicks hatched from two flocks of 61-wk old Ross 708 broiler breeders (Trial 5)[1].

Response Variable	Pre-incubation Warming (Hrs)				
	0	9	12	15	P > F
INWT	45.1 ± 0.6	42.3 ± 1.0	40.8 ± 0.6	42.2 ± 0.6	0.0032
FWT	596.0 ± 10.8	572.0 ± 17.0	545.0 ± 12.1	572.2 ± 11.3	0.0837
ADG	30.3 ± 0.5	28.5 ± 0.8	27.2 ± 0.8	29.0 ± 0.6	0.2012
FCR	1.37 ± 0.02	1.34 ± 0.01	1.35 ± 0.04	1.38 ± 0.03	0.6492

[1] Values are means ± SEM.

Table 12. The effects of pre-incubation warming of 0, 9, 12, and 15 hrs on initial weight (INWT), final weight (FWT), average daily gain (ADG), and feed conversion ratio (FCR) on Ross 708 male broiler chicks hatched from two flocks of 61-wk old Ross 708 broiler breeders (Trial 6)[1].

Response Variable	Pre-incubation Warming (Hrs)				
	0	9	12	15	P > F
INWT	48.7 ± 0.5	46.6 ± 0.9	47.4 ± 0.7	45.0 ± 0.4	0.0046
FWT	603.4 ± 15.1	591.7 ± 15.2	641.8 ± 10.6	589.7 ± 17.2	0.0731
ADG	31.1 ± 0.9	31.0 ± 0.6	32.7 ± 0.6	30.8 ± 0.4	0.3085
FCR	1.43 ± 0.02	1.44 ± 0.02	1.39 ± 0.02	1.38 ± 0.02	0.1880

[1] Values are means ± SEM.

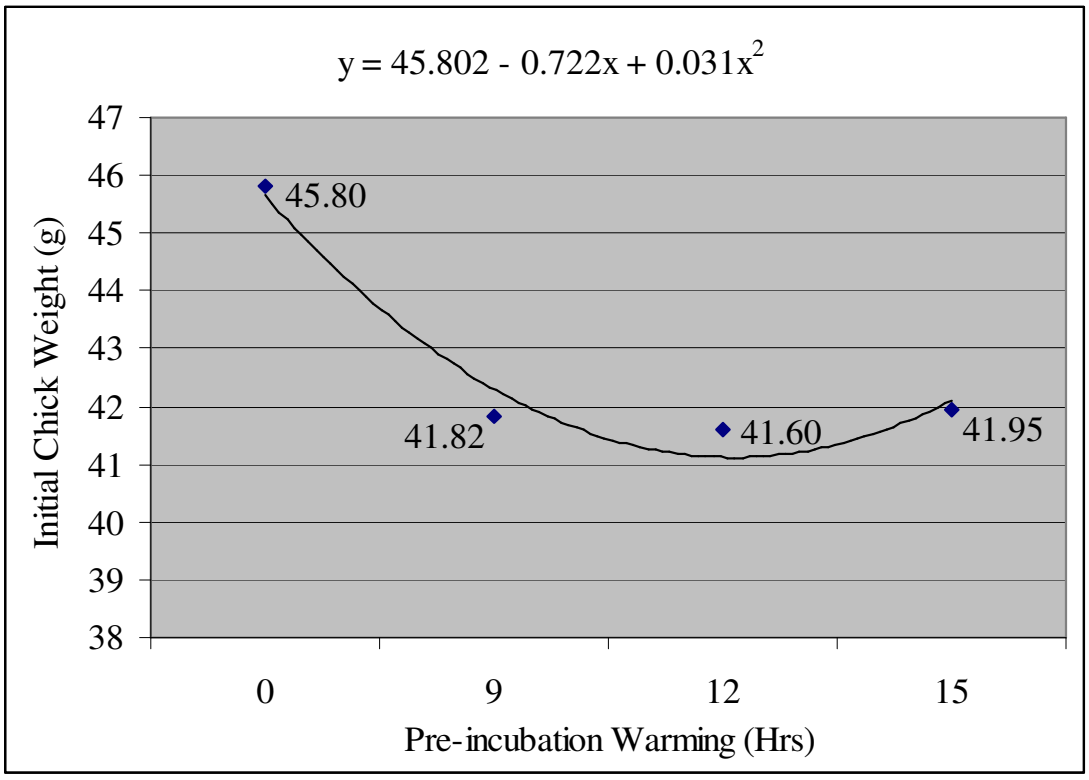

Figure 6. The effect of pre-incubation warming of 0, 9, 12, and 15 hrs on initial chick weight of chicks hatched from two flocks of 61-wk old Ross 708 broiler breeders (Trial 5).

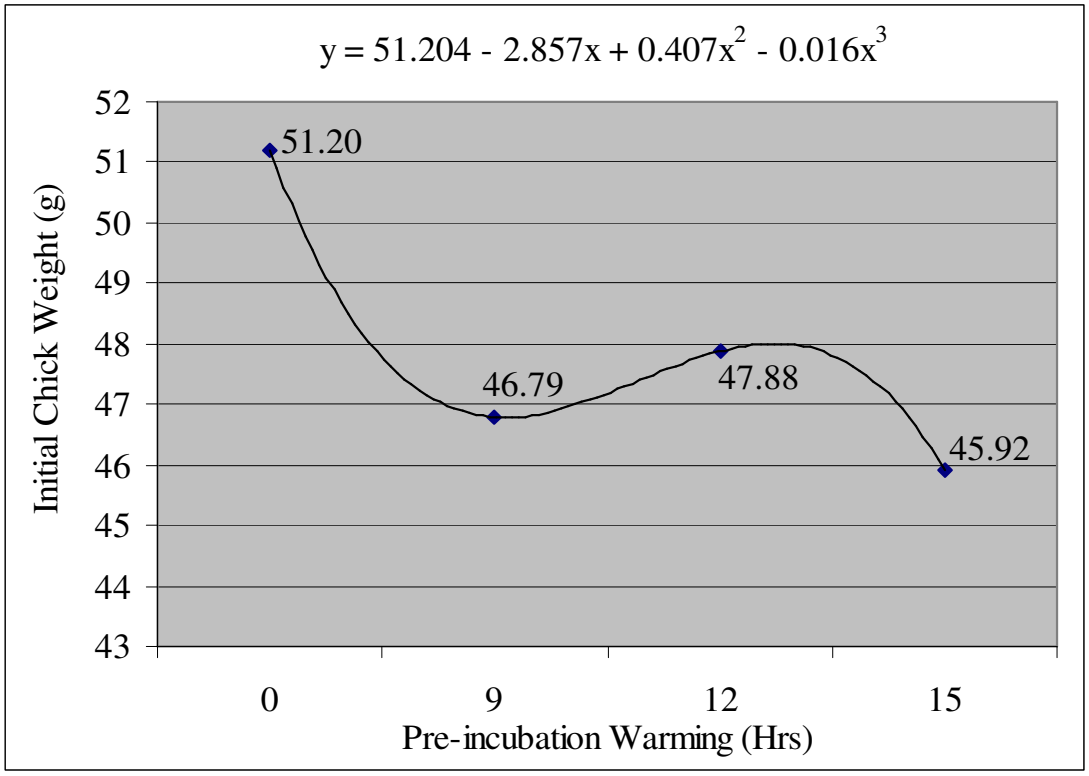

Figure 7. The effect of pre-incubation warming of 0, 9, 12, and 15 hrs on initial chick weight of chicks hatched from two flocks of 61-wk old Ross 708 broiler breeders (Trial 6).

Romanoff, 1936). Since these were older breeders, they produced larger eggs which resulted in heavier chicks. Despite the significant differences in initial weight (INWT), there was no significant difference between treatments with regard to final weight (FWT), average daily gain (ADG), or feed conversion ratio (FCR) at the end of the 18d trial period. The male chicks used in this study did not meet the performance objectives with regard to ADG, or FCR (Aviagen, 2007). The ADG for Ross 708 males at 18d of age should be approximately 51g, with a FCR of 1.23 (Aviagen, 2007). The males in this study had an ADG of 28.7g and 31.4g, for Trials 5 and 6, respectively (Tables 11 and 12). Their corresponding FCRs were 1.36 and 1.41. This too can be explained by the delay to pull chicks from the hatcher at optimum hatch time. The methodology of determining hatch time made it necessary to hold chicks in the hatcher at least 12 hrs beyond what would be considered the right pull time, as the remainder of the chicks continued to hatch. Consequently, all chicks used in the battery trials were dehydrated to some degree, and thus hindered from maximizing their growth potential. Dakessian (2005) described the importance of hatchery management in the prevention of dehydrated chicks. He advises against leaving chicks in the hatcher for as little as five hours after the right pull time, as the delay can cause dehydration in the chick. The chick responds to an improper hatching environment by over-utilizing the yolk to survive, and later is less able to cope with conditions that cause further dehydration during the brooding stage. Therefore, it seems likely that dehydration of the chicks used in these studies is the cause of their failure to meet their appropriate performance objectives.

SUMMARY

This study was conducted to determine the effect of pre-incubation warming (for 0, 2, 4, 6, and 0, 3, 6, and 9 hrs) on the percentage of fertile hatchability, total hatchability, dead embryos, and pips in eggs from post-peak Ross 308 broiler breeders. This study was also conducted to determine the effect of pre-incubation warming (for 0, 9, 12, and 15 hrs) on hatch time, initial weight, final weight, average daily gain, and feed conversion ratio of eggs and chicks from post-peak Ross 708 broiler breeders. The results of this study can be summarized as follows:

1) The percent fertile hatchability, total hatchability, mid-dead, late dead, and total unhatched eggs were not significantly affected by pre-incubation warming for lengths of 12 hrs or less. The percent early dead mortality was significantly affected by pre-incubation warming of 15 hrs. In the same treatment, the percent pipped eggs was significantly reduced by pre-incubation warming.

2) Average hatch time was reduced when eggs were pre-incubated for 9, 12, and 15 hrs.

3) Average initial chick weights were significantly reduced by pre-incubation warming of 9, 12, and 15 hrs, as it increased the length of time the chicks remained in the hatcher. However, final weight, average daily gain, and feed conversion ratio were not significantly different at 18d of age. These values were, however, lower than the June 2007 performance objectives for Ross 708 broilers.

CONCLUSIONS

The following conclusions are based on the results of this experiment:

It appears that the pre-incubation warming treatments used in this experiment were not beneficial in improving:

1) fertile hatchability

2) total hatchability

3) embryonic mortality

4) broiler performance

This may have occurred due to the lack of a biologically stressful storage period. Previous work that showed significant effects on these variables involved storing eggs for periods of time that are considerably longer than the period used in this study. This study aimed to produce results that would be of value to the commercial industry by working within the limitations of normal commercial practice. Despite our efforts, it appears pre-incubation warming may only be of benefit to eggs requiring prolonged storage.

Pre-incubation warming for periods of up to 15 hrs did not negatively affect hatchability. This finding violates the strong beliefs of both the commercial and academic communities which strictly adhere to the practice of cooling eggs immediately after collection for storage.

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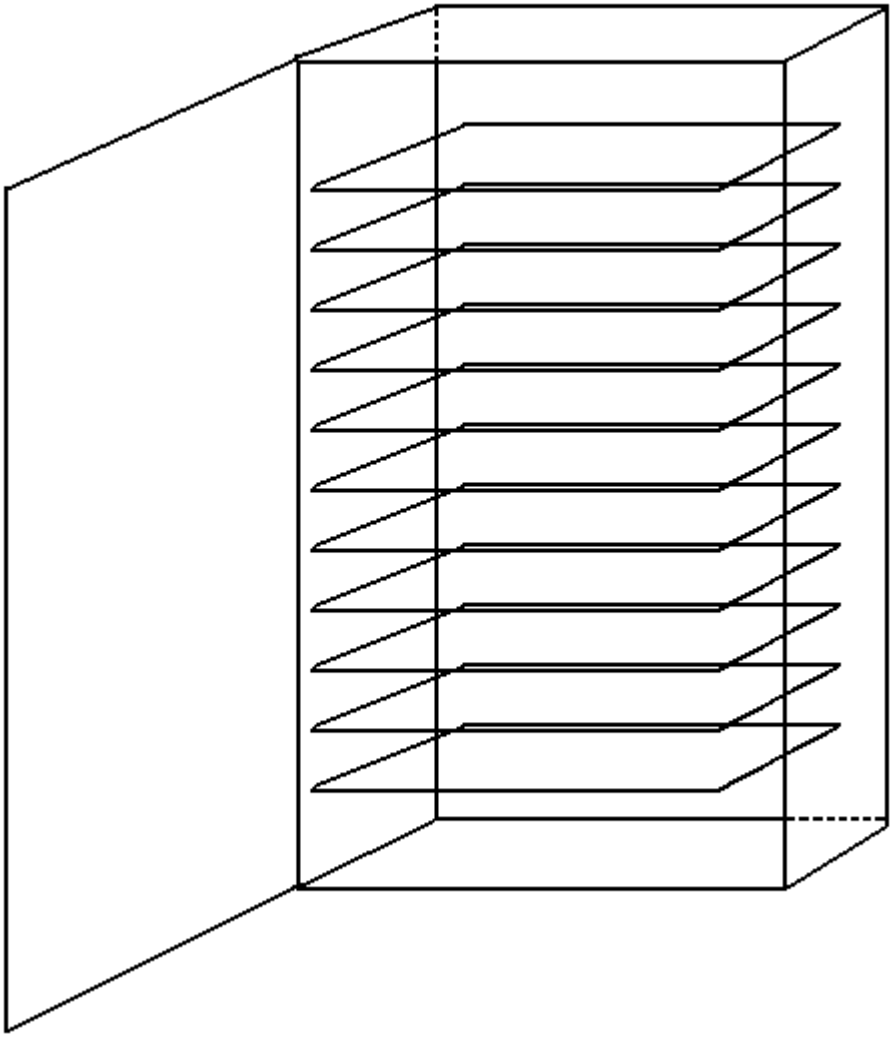
APPENDIX: NATUREFORM© SETTER 2000



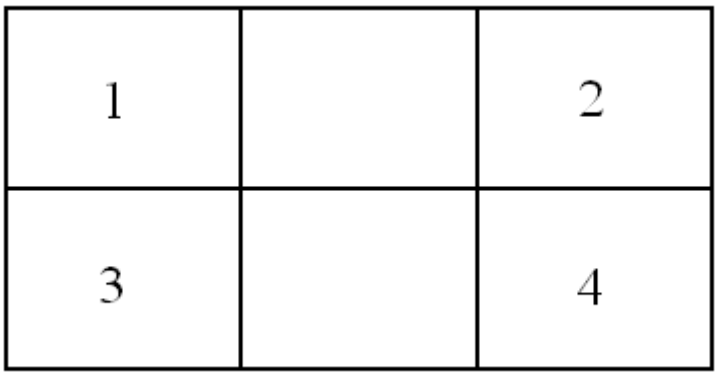


Figure A1. Natureform© Setter 2000 showing eleven levels, and position of experimental eggs within a level.

VITA

Cameron Benjamin Wiggins II was born in Charleston, South Carolina, in September of 1983. He is the oldest son of Ben and Cheryl Wiggins, and has one younger brother, Brandon. His father, Ben Wiggins, recently retired from the US Navy after serving 23 years as an E.O.D. bomb/dive specialist. As a result, Cameron attended elementary school in five different states, including North Carolina and Hawaii, before beginning High School on Whidbey Island, Washington State. During his junior and senior year of High School, he attended Skagit Valley Community College full time through a program called "Running Start." He ultimately graduated from High School and Community College on the same day with both his HS Diploma, and Associates Degree in Liberal Arts in 2001. After graduation, Cameron attended North Carolina State University in Raleigh, North Carolina, for four years. He graduated in May of 2005 with a double-major in animal science and poultry science. He entered the Graduate School at Louisiana State University in August of 2005 under the direction of Dr. Dennis Ingram in poultry science. He is now a candidate for the degree of Master of Science in the combined department of Animal, Dairy and Poultry Science.